

MULTIFRACTAL ANALYSIS OF UTERINE EMG SIGNALS FOR THE ASSESSMENT OF PROGRESSION OF PREGNANCY IN TERM CONDITION USING HURST EXPONENT

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ABSTRACT

Uterine Electromyography (uEMG) is a non-invasive technique that measures the electrical activity of the uterus and can detect its transition from the normal gestation to the active labor state. In this work, an attempt has been made to study the progression of pregnancy in term condition (gestation age > 37 weeks) using uEMG signals and Multifractal Detrended Fluctuation Analysis (MFDFA). For this study, the signals are obtained from the abdominal surface before (TE_1) and after (TE_2) 26 weeks of gestation from a public database. MFDFA method is applied on these signals to compute the generalized Hurst exponent. From the exponent, six features namely, maximum (HE_{MAX}), minimum (HE_{MIN}) and zero order exponent (HE_0), degree of multifractality (DOM), degree of small (DSF) and large (DLF) fluctuations are extracted for analyzing the signals. These features are statistically analyzed using Wilcoxon rank sum test. Coefficient of variation is computed to examine the variation of the features among different subjects. The results show that the extracted generalized Hurst exponent reveals the multifractal behavior of uEMG signals. It is also observed that, four features namely, HE_{MAX}, HE_0, DSF and DLF show high statistical significance ($p < 0.005$) in differentiating signals in TE_1 and TE_2 groups. Among these features, HE_{MAX} and HE_0 have least inter-subject variability in detecting the progress of pregnancy. Hence, it appears that the multifractal Hurst features can aid in examining the progressive variations in the contraction of uterine muscles during pregnancy.

Keywords: Term condition; Uterine electromyography; Multifractal detrended fluctuation analysis; Hurst exponent

INTRODUCTION

The uterus, being a contractile organ, consists of smooth muscles (myometrium) which contract vigorously during labor to expel the fetus [1]. These contractions are direct consequence of the underlying cellular electrical activity which is less and unsynchronized during early stages of gestation, but becomes strong and coordinated as pregnancy progresses. Hence, monitoring uterine contractions during pregnancy is crucial to differentiate ineffective normal contractions from the effective ones which might induce preterm birth [2].

Uterine electromyography (uEMG) is a non-invasive technique that represents the electrical activity triggering the mechanical contractions of the myometrium [3]. The uEMG signals can be recorded from the 19th week of gestational age (WOG). Also, as pregnancy advances and labor approaches, uterine electrical activity undergo changes that can be identified from the uEMG signals' temporal and spectral characteristics [4]. Therefore, this technique could provide useful information to monitor pregnancy and for measuring uterine contractions efficiently [3-4].

The biological signals are generated from complex self-regulating systems and possess scale invariant properties [5]. Scaling behavior is an indicator of the signal complexity. Several signal processing algorithms have been applied to study the characteristics of the uEMG signals. However, due to its complex and non-stationary nature, the conventional features are not able to address the complexity in these signals [6]. Fractal analyses estimate a non-integer parameter known as fractal dimension, which